

Why are AHP results not binding for appraising real estate?

Miguel Camacaro Pérez, M.Sc

Appraisers Reading Club, Calle Buenos Aires, 9, 1C, 28850, Torrejón de Ardoz, Madrid, España. mundovalor@gmail.com

ABSTRACT

Using the method of reduction to absurdity, an initial hypothesis was considered: the results of the general weighting vector of AHP are not linked to real estate market prices, as opposed to the alternative hypothesis that they are linked. To demonstrate this, a "real fable" was used to explain the valuation of a medieval castle. The first example was based on three criteria: quality of the environment, quality of the castle, and state of conservation; and six alternatives, five comparables plus the property being appraised (3C+6A), completing three more cases. Using AHP, the elements of the global vector of the alternatives were determined. With the offer prices and the use of Valuation Ratio (RV), the value of the property and the values of the comparables were estimated for comparative analysis. The Non-Ratio Reciprocity Test (NRRT) was used, obtaining significant percentage differences between the values and prices of the comparables, not guaranteeing reciprocity to validate the initial estimates of the appraised property value. In the second example, three different criteria were used: strength, security, and access; the same six alternatives were used (3C+6A). It was possible to demonstrate the inconsistency of the results due to the disparity of the values obtained in all cases of the two examples for the appraised property, which does not allow for guaranteeing reliable market values. For the third example, the database simulation was performed based on the information from the original sample, with 8 explanatory variables, to obtain 69 data points. Econometric modeling was carried out, demonstrating that there is no correlation between the explained variable (unit price) and the explanatory variables as a whole, much less individually, therefore, the results are not reliable. Despite the non-fulfillment of the basic assumptions of MRLM, point and interval estimation was done. These values were similar to those obtained in the second example, using AHP+RV. With this evidence, the analyzed proposal does not guarantee market values; therefore, the initial hypothesis is correct.

Key words: AHP, models, valuation, real estate, MRLM.

1. INTRODUCTION

The science of valuation integrates elements of economics, finance, statistics and law to determine the value of property and assets. Throughout history, this discipline has evolved significantly, adapting to economic changes and the needs of society.

Numerous procedures and methods have been proposed from different areas of knowledge, and their adoption and adaptation have enriched research in this field. This has made valuation an essential discipline for study and practice in the modern global economy.

An example of this adoption is the interdisciplinary field called Operations Research, which has a branch that explicitly evaluates multiple criteria, which is the Multiple Criteria Decision Making (MCDM), being one of the established methods, the Analytic Hierarchy Process (AHP)¹, that Thomas Saaty developed in the 1970s and 1980s.

Since its appearance, the method proposed by Saaty and his collaborators has been highly praised and popular among its users. It is a method created to solve problems of selection of alternatives for complex decision making.

At the beginning of the 21st century, professors at the Universidad Politécnica de Valencia² (Spain) introduced a procedure using the AHP plus a Valuation Ratio as an alternative valuation method. Today, Latin American appraisers have adopted it as their own, without any of the advocates of the use of the AHP method³, that have won awards at valuation congresses of the UPAV⁴, have presented empirical evidence to support the use of the valuation ratio to "leverage" the AHP ranking.

Although I knew about the proposal since its beginnings, I was never interested in studying it because it seemed to me a rather subjective method to be applied to real estate valuation, and because I was caught by the teaching of the Brazilian school. However, years later, seeing the boom in the use of this procedure among Latin American appraisers, I was curious to know why they considered it as a reliable alternative procedure to value real estate.

I took the initiative to study the origins of MCDA, in particular the AHP multi-criteria method. As a result of my research, I made a first observation on the results of the AHP + Valuation Ratio, introducing the Non-Ratio Reciprocity Test (NRRT), which showed that the elements of the global vector of alternatives are not binding to determine deterministic market values.

Also, with Monte Carlo scenario simulations it was shown that the probabilistic estimation of the results does not generate reciprocity between the values of the analyzed properties when they are removed or increased comparable in the sample analyzed through AHP and the valuation ratio. The application of the procedure is limited to the use of small samples, most of the times they do not exceed six comparables + six variables, not complying with the contents of the valuation standards⁵, therefore, the results are punctual but not valid, since they do not allow generalization to obtain market values.

The purpose of this work is to formalize this research, therefore, in the Methodology section, the theoretical bases of the Analytic Hierarchy Process (AHP), the Direct Comparative Method of Market Data, based on the Brazilian valuation standards ABNT NBR 14653-2, and the Method of Reduction to the Absurd are succinctly presented. In the results, the hypotheses considered are presented, followed by a demonstration using a "real fable" where three examples are developed, using the AHP + Valuation Ratio and the Multiple Linear Regression Model (MLRM). Then, the Discussion and Conclusion sections are presented, where the formality of the methodological proposal resulting from the research work is presented.

2. METHODOLOGY

For the development of this article, it is very important to briefly explain the Analytic Hierarchy Process (AHP), the Comparative Market Data Method and the Reduction to Absurdity Method.

¹ See the video 5 TMDII - Information about *Analytic Hierarchy Process* (AHP) in: <https://youtu.be/oRVA-2fhrM4>

² Multicriteria Group UPV <https://www.upv.es/contenidos/VMULTIC/infoweb/vmultic/info/1068975normalc.html>

³ A review was done at ISAHP from 1998 to 1992 and there is no evidence of such work. <https://www.isahp.org/proceedings/>

⁴ The Pan-American Union of Valuation Associations (UPAV) is an organization that brings together various valuation associations from different Latin American and European countries.

⁵ Orden ECO/805/2003, of March 27, 2003, on rules for the valuation of real estate and certain rights for certain financial purposes (Spain).

2.1 Analytic Hierarchy Process -AHP

Thomas Saaty introduced the Analytic Hierarchy Process (AHP) in the 1970s and the Analytic Network Process (ANP) more recently. Among his co-authors and colleagues are Ernest Forman and Luis Vargas. Saaty was one of the most successful people in the field of information management and communications⁶ in the dissemination of his method for complex decision making. It provides a systematic methodology for evaluating and comparing multiple criteria and alternatives. The consistency of comparisons is crucial; inconsistent decisions can lead to unreliable results. In summary, the AHP facilitates well-founded, coherent, and transparent decisions, although it should always be considered as part of a broader decision-making process.

2.2 Direct Comparative Market Data Method

In point 8.2.1.4.3 of the ABNT⁷ NBR 14653-2, it refers to scientific treatment and expresses that whatever models are used to infer market behavior and the formation of its values, their assumptions must be adequately explained and tested. When discussing factors that affect the market value of real estate, it is necessary to use a model, and this is nothing more than a simplified representation of market reality. Econometric models are a particular class of models that aim to quantify relationships between variables based on underlying economic laws. Models that relate the price of a property to its characteristics are known as hedonic price models, with the linear regression model being used to represent the real estate market.

2.3 Method of reduction to absurdity⁸

Reduction to absurdity (or *reductio ad absurdum*) is a technique of argumentation and demonstration used to establish the truth of a proposition or situation by showing that assuming the opposite leads to a contradiction or an absurd result. It can be applied in various fields, mainly in logic, mathematics, philosophy and science, but also in everyday situations and legal argumentation.

It consists of temporarily assuming the opposite of what one wants to prove, and then demonstrating that this assumption leads to a contradiction or an absurd result. This implies that the initial assumption is false, therefore, the original statement must be true.

3. RESULTS

First, we start from the hypotheses of the reduction to absurdity method:

- Initial hypothesis: the results of the general weighting vector of the AHP are not linked to real estate market prices.
- The alternative hypothesis is: The results of the general weighting vector of the AHP are linked to real estate market prices.

The method was developed and tested using the following fable: One day, a king⁹ from a European country decided to give the crown prince a new castle, with all the luxuries and comforts. A nobleman became aware of the royal intentions, although his castle (henceforth referred to as Castle N), constructed on a 15-hectare plot with a built-up area of 1,500 square meters, was not for sale at that time. He decided to offer it to His Majesty, but there was a problem: he had not considered the price offered. There was a skilled valuer at the court who could accurately estimate the most probable price of the castle so that the best decision could be made for both parties. The King provided the market sample to the valuer to

⁶According to the content of the Part of the history of Multiple Criteria Decision Making (MCDM) taken from The International Society on Multiple Criteria Decision Making website. Retrieved from:

<https://www.mcdmsociety.org/content/short-mcdm-history-0>

⁷ ABNT stands for the Brazilian Association of Technical Standards, the body responsible for standardization in Brazil. The acronym NBR refers to Brazilian Standards, in this case, NBR-14653 Part 2. Appraisals of Urban Assets.

⁸ In this article you can read more about this topic: <https://definicion.com/reductio-ad-absurdum/>

⁹ Article inspired by: *Malba Tahan* (1938). "The Man Who Calculated". Chapter 16 "Legend about the game of chess by *Beremís Samir*".

perform the calculations and determine the market value of the property, complying with the royal valuation standards. The information provided by His Majesty is contained in this table¹⁰:

Table 1: Comparables of the medieval castle market in Europe¹¹

Source of information	Comparable	Total Price [UM]	Land area [ha]	Construction area [m ²]	Unit price [UM/m ²]
www.real2.com	Castle 1	2.475.000,00	20,00	1.500,00	1.650,00
www.majestic.com	Castle 2	3.000.000,00	15,00	2.500,00	1.200,00
www.castle.com	Castle 3	5.512.500,00	30,00	3.500,00	1.575,00
www.luxury.com	Castle 4	4.080.000,00	25,00	2.000,00	2.040,00
www.nobile.com	Castle 5	12.400.000,00	20,00	4.000,00	3.100,00

The valuer recalled a proposal brought from Europe to America, based on the use of a valuation ratio utilizing the elements of the global vector of alternatives in the Analytic Hierarchy Process (AHP). To adopt this valuation procedure, he considered, according to his judgment, three compelling elements: sample size, property characteristics, and report delivery time. Once the decision on the procedure to be used was made, he quickly convened five expert valuers from the kingdom to assist him with their opinions to define the reciprocal pairwise comparison matrices of the criteria and the alternatives by the criteria. For Case 1 (3C+6A), the following matrix of criteria was the solution provided by the group of experts (normalized synthesis¹²), based on Saaty's fundamental scale:

Table 2: Reciprocal matrix of criteria and priority vector¹³

Criteria	Quality of the environment	Quality of the castle	State of conservation	Vector priority
Quality of the environment	1	1/3	1/4	0,12196
Quality of the castle	3	1	1/2	0,31962
State of conservation	4	2	1	0,55842
Consistency ratio = 1,76 %				

The table presents the results of the calculations for the selection of the best alternative, namely, the global vector with the rankings based on the judgment of the expert valuers:

Table 3: Global vector results and ranking of alternatives

Castle	Quality of the environment	Quality of the castle	State of conservation	Vector priority criteria	Normalized global vector	Ranking
Castle 1	0,08247	0,0890	0,2559	0,12196	0,1814	3
Castle 2	0,03282	0,0343	0,0428	0,31962	0,0389	6
Castle 3	0,03282	0,2355	0,0947	0,55842	0,1322	4
Castle 4	0,20688	0,0890	0,2559		0,1966	2
Castle 5	0,43813	0,4630	0,2559		0,3443	1
Castle N	0,20688	0,0890	0,0947		0,1066	5

¹⁰ The unit prices in the following table are obtained by dividing the total price of the comparable by the construction area.

¹¹ The sources consulted are fictitious. The values of the variables indicated in the table are also fictitious, except for the unit values, which were taken from the example of the urban property in the book "New valuation methods Multi-criteria models" by Jerónimo Aznar and Francisco Guijarro (2012) p. 92 to 95. The values of the reciprocal matrices of paired comparisons of the criteria and the alternatives by the criteria of the first example of this essay are also from this reference.

¹² Solomon (2016). Normalizing priorities creates a dependency between them. However, by removing an old alternative or inserting a new one, normalized priorities can cause illegitimate changes in the rank of the alternatives, which is known as Rank Reversal-RR. The Rank Reversal-RR video on AHP is available on the Mundo valor channel. You can access it through this link <https://youtu.be/5TkAxT4kDPA>

¹³ In all the tables of the reciprocal matrices, at the bottom, appears the consistency ratio that is used to measure the consistency of the judgments of the paired comparisons. On the Mundo Valor channel there is the video "Calculation of the Consistency Ratio" that you can access through this link https://youtu.be/bCJr_THM-2Y

As can be observed, Castle 5 obtained the highest value among the elements of the normalized global vector (0.3443), ranking first. As for Castle N, with a value of 0.1066, it occupied the fifth position in the selection process. The valuer proceeded to use a mathematical artifice called a "Valuation Ratio" to determine the value of Castle N:

$$\text{Valuation Ratio} = \frac{\sum \text{Comparable property prices}}{\sum \text{Weighting of comparable properties}} \quad (1)$$

The results of the calculation are tabulated below:

Table 4: Castle N Unit Value Results based on Valuation Ratio

Castle	Unit Value [UM/m ²]	Vvg [adim]	Valuation Ratio [UM/m ²]	Vvg N [adim]	Unit Value N [UM/m ²]
Castle 1	1.650,00	0,1814	10.706,17	0,1066	1.141,17
Castle 2	1.200,00	0,0389			
Castle 3	1.575,00	0,1322			
Castle 4	2.040,00	0,1966			
Castle 5	3.100,00	0,3443			
Total	9.565,00	0,8934		1,0000	

From this table, the unit value of Castle N of 1,141.77 UM/m² was extracted, therefore, the total value of the property was calculated:

Table 5: Total value of the Castle N¹⁴

Castle	Construction area [m ²]	Unit Value [UM/m ²]	Total Value [UM]
Castle N	1.500,00	1.150,00	1.725.000,00

In order to compare the results of the valuation procedure, the King deemed it necessary to resolve the following cases:

- Case 2 (3C+5A): excluding Castle 2, which was no longer for sale.
- Case 3 (3C+5A): including Castle 2 and excluding Castle 4.
- Case 4 (3C+7A): including Castle 6.

With these results, the valuer completed the information and was responsible for analyzing the ranking for each case. Therefore, the following comparative table was created.

Table 6: Comparison of ranking of alternatives by case

Castle	Original case 6A	Case 5A (-2)	Case 5A (-4)	Case 7A (+6)
Castle 1	3	3	2	2
Castle 2	6	NA	5	7
Castle 3	4	4	3	5
Castle 4	2	2	NA	4
Castle 5	1	1	1	1
Castle 6	NA	NA	NA	3
Castle N	5	5	4	6

¹⁴ The unit value of 1,141.17 UM/m² was rounded to 1,150.00 UM/m² to obtain whole numbers and improve the presentation of the example.

As you can see, there is a rank inversion¹⁵ among the other alternatives. For example, Castle 1 was the third option in the first two cases, but then it moved up to second place in the following two cases. To visualize the overall results, the valuer presented a summary of the calculations performed in this phase of the research:

Table 7: Comparison of unit and total values for each individual case

Case	Unit Value [UM/m ²]	Total Value [UM]
Original case 6A	1.150,00	1.725.000,00
Case 5A (-2)	970,00	1.455.000,00
Case 5A (-4)	1.200,00	1.800.000,00
Case7A (+6)	1.320,00	1.980.000,00
Mean	1.160,00	1.740.000,00
Standard Deviation	145,37	218.059,62
Coefficient of Variation	12,53%	12,53%

Upon reviewing the results, the King proposed conducting a simple adjustment test known as the Non-Ratio Reciprocity Test (NRRT). This test involves calculating the percentage difference between the estimated value and the offered price of comparable properties using the Valuation Ratio, as expressed by the following formula:

$$NRRT = \frac{\text{Estimated value} - \text{offered price}}{\text{offered price}} \quad (2)$$

Table 8: Comparison of the results of the unit, total and NRRT values for each case

Castle	Offers	Original Case		Original Case (-A2)		Original Case (-A4)		Original Case (+1A)	
		Unit Value [UM/m ²]	NRRT [adim]	Unit Value [UM/m ²]	NRRT [adim]	Unit Value [UM/m ²]	NRRT [adim]	Unit Value [UM/m ²]	NRRT [adim]
1	1,650.00	2,007.09	22%	1,804.97	9%	2,193.26	33%	2,326.96	41.03%
2	1,200.00	384.63	-68%	NA	NA	382.98	-68%	422.99	-64.75%
3	1,575.00	1,390.80	-12%	1,164.02	-26%	1,341.61	-15%	1,572.53	-0.16%
4	2,040.00	2,120.60	4%	1,885.37	-8%	NA	NA	1,764.75	-13.49%
5	3,100.00	3,994.44	29%	3,663.18	18%	4,063.90	31%	5,102.38	64.59%
6	3,000.00	NA	NA	NA	NA	NA	NA	1,878.27	-37.39%
N	NA	1,141.17	0%	969.40	0,00%	1,192.61	0%	1,192.05	0,00%

The appraiser, in an interesting discussion with colleagues, was able to conclude the following:

- In all cases, all castle values were very different, especially for Castle 2, where with a price of 1,200 UM/m², the values range between 382.98 and 422.99 UM/m² with a maximum NRRT of -68%.
- For Castle N, it was observed that the values ranged from a minimum of 969.40 UM/m² to a maximum of 1,192.61 UM/m², representing a 23% variation compared to the lowest value.
- When a castle is removed, both positive and negative NRRTs are observed, indicating both underestimation and overestimation of the initial prices.
- For the six alternatives, there were radical changes in the estimated values, reflected in the high percentages of the NRRT.
- The valuation ratio differed in all cases.

¹⁵ It is recommended in these cases to use the ideal Absolute/Synthesis Mode to mitigate rank inversion in AHP.

Once the report was presented, the King, with his characteristic serenity and despite not being an expert in the matter, conducted an even more conservative reading. Knowing that it was not his specialty, he considered consulting the kingdom's wise Analyst, to whom he posed the following:

«We are in the presence of two very different procedures with different objectives. In the first, an attempt is made to solve a Selection problem - $P\alpha$ ¹⁶. The desired result is a choice based on multiple criteria. The mathematically determined values, which are dimensionless, are directly linked to the measurement of the criteria and the alternatives at the considered hierarchical levels. To verify the lack of linkage with market prices, let's perform the exercise considering the characteristics: strength, security, and access to the castles. The reciprocal comparison matrices of the criteria and of the alternatives by the criteria were generated:

Table 9: Reciprocal matrix of criteria and priority vector

Criteria	Strength	Security	Access	Vector normalized priority
Strength	1	1/4	1/4	0.10852
Security	4	1	2	0.54693
Access	4	1/2	1	0.34454

Consistency ratio= 5,16%

Once the priority vectors for the criteria and the alternatives per criterion were obtained, the global vector and the ranking were calculated, as shown in the following table:

Table 10: Results of the global vector and ranking of the alternatives

Castle	Strength	Security	Access	Vector priority criteria	Normalized global vector	Ranking
Castle 1	0.04980	0.3550	0.1740	0.10852	0.2595	3
Castle 2	0.23309	0.0747	0.0501	0.54693	0.0834	6
Castle 3	0.11560	0.0715	0.2399	0.34454	0.1343	4
Castle 4	0.05777	0.0864	0.3087		0.1599	2
Castle 5	0.38047	0.2143	0.0692		0.1823	1
Castle N	0.16328	0.1981	0.1582		0.1806	5
Consistency ratio=	7.88 %	7.80 %	9.79 %	5.16 %		

Using the element values for each alternative from the normalized global vector and following the previously explained procedure, the unit value for Castle N was determined and can be seen in the following table:

Table 11: Results of the Unit Value of Castle N based on the Valuation Ratio

Castle	Unit Value [UM/m ²]	Vvg [adim]	Valuation Ratio [UM/m ²]	Vvg N [adim]	Unit Value N [UM/m ²]
Castle 1	1,650.00	0.2595	11,672.56	0.1806	2.107.56
Castle 2	1,200.00	0.0834			
Castle 3	1,575.00	0.1343			
Castle 4	2,040.00	0.1599			
Castle 5	3,100.00	0.1823			
Total	9,565.00	0.8194		1.0000	

¹⁶ Gomes, C. F. S., & Costa, H.G. (2015). *Aplicação de métodos multicritério ao problema de escolha de modelos de pagamento eletrônico por cartão de crédito*. *Production*, 25(1)

We now proceed to calculate the total value of Castle N:

Table 12: Total value of Castle N

Castle	Construction area [m ²]	Unit Value* [UM/m ²]	Total Value [UM]
Castle N	1,500.00	2,100.00	3,150,000.00

*rounded

Now, a comparison is made with the results obtained, which are shown in the following table:

Table 13: Comparative table of the total value of Castle N

Case	Unit Value [UM/m ²]	Total Value [UM]	Percentage difference
1	1,150.00	1,725,000.00	
2	2,100.00	3,150,000.00	82.61 %

As can be clearly seen, Your Highness, there is a significant 82.61% difference between the two cases, which is sufficient evidence to conclude that the results of the global vector of alternatives are not bound to market prices. Although the AHP was correctly applied, the mathematical artifice does not guarantee reliable real estate market values. That is all, exclaimed the wise Analyst. I now give the floor to the wise Regressor to present his knowledge on this controversial procedure».

The wise Regressor stated the following:

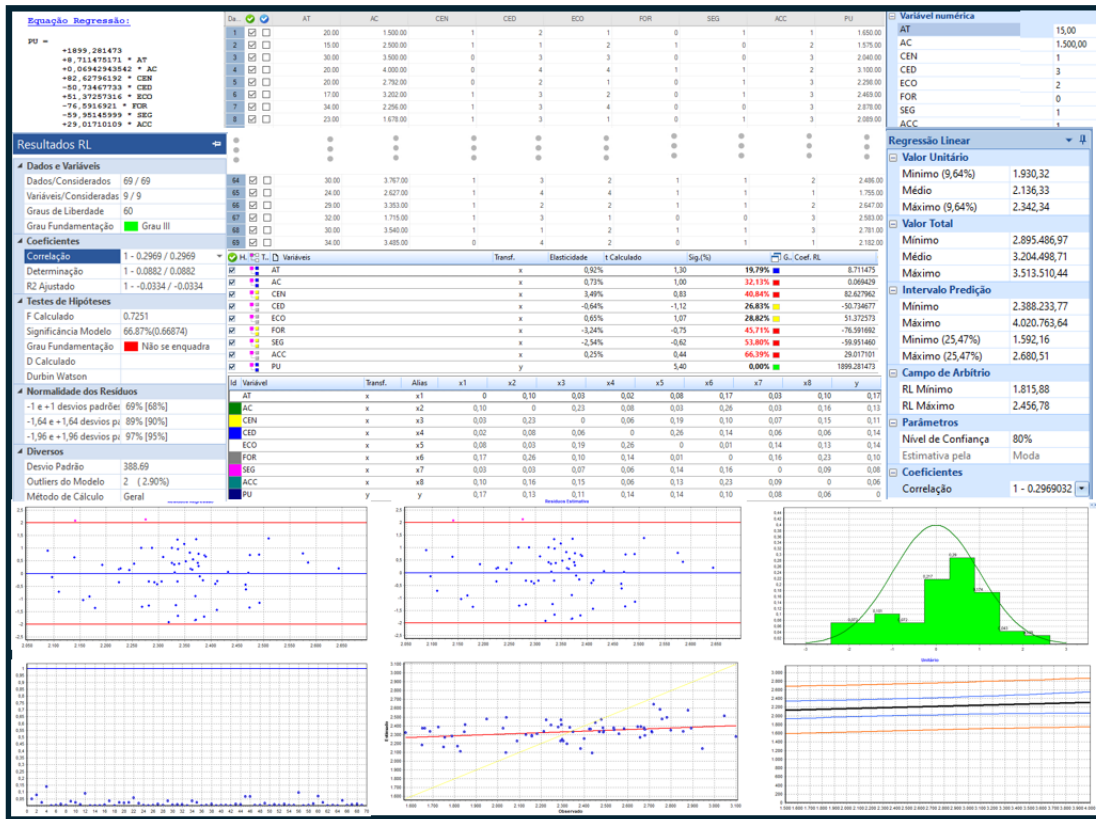
«I agree with the wise Analyst's position, as scientifically speaking, they are two procedures with very different and independent objectives and results. Due to the size of the sample used, there is a violation of the standards and, likewise, a thorough investigation was not carried out for the selection of variables, which would have allowed the appraiser to know if they are statistically significant¹⁷. As an exercise to further empirically substantiate the inappropriateness of using AHP+RV in real estate valuation, I present to you, with all due respect, Your Highness, an analogous situation considering econometric models.

For the sample of comparable castles¹⁸ a simulation was performed using the Excel function «RANDBETWEEN()» considering the maximum and minimum values of the variables in Table 1. The results of the regression model calculation are as follows (use the SISDEA Program):

¹⁷ See Camacaro & Mock (2022) "An econometric model + Analytic Hierarchy Process (AHP) to select the best alternative for a real estate investment. case: apartment in Panama City". <https://youtu.be/vrDYJJtJsc>

¹⁸ The sample size was 69, according to numerology, which is the study of the relationship between numbers, letters and number is related to humility, humanity and good communication. <https://www.oroscopissimi.it/numerologia/numero-69.htm>

Figure 1- Multiple linear regression model results



With respect to the MRLM results analysis, the following can be stated:

Table 14: Results of the MRLM test statistics

Statistic	Value	Observations
Correlation coefficient (r)	0,30	A weak correlation between the explained variable and the explanatory variables.
Coefficient of determination (R^2)	0,0882	8.82 % of the variation in unit values around the mean is explained by the independent variables included in the model. 91.18 % of the variations are unexplained.
Calculated F	0,7251	The level of significance of the model is 66.87 %, which is greater than the significance level α , so the null hypothesis is accepted, therefore the independent variables included in the model are not important for explaining the variability of prices observed in the market.
Significance of population estimators	19,79 - 66,39 %	The regressors of the variables are not statistically significant for the Level III Foundation.
Standard deviation	388,69	Represents 18.19% of the estimated mean value of the property.
Outliers	2,90 %	Within the tolerance of < 5%.
Cook's distance	0	No presence of influential points.

Given these results, the MRLM is rendered invalid without the need to assess further basic assumptions or model specification errors. For comparative purposes, a point estimate for castle N is calculated at 2,136.33 UM/m². Assuming a unit value of 2,200.00 UM/m², the taxable value of the property can be determined

Table 15: Total value of taxable property (Castle N)

Castle	Construction area [m ²]	Unit Value* [UM/m ²]	Total Value [UM]
Castle N	1,500.00	2,200.00	3,300,000.00

*Rounded

The result obtained lacks a solid empirical basis, as shown in the MRLM calculations and the AHP+RV estimate (3,150,000 UM). While the difference between the two is only 4.76%, it's just a coincidence. Both methods are biased and don't accurately reflect real estate market prices. Even if AHP is used correctly, the Valuation Ratio doesn't guarantee realistic value».

Once the consultation was over, there was nothing left to talk about, the King said he had finished the activity, thanking those who knew him for his important and clarifying information, but he asked the Real Appraiser who remained in the Castle because he had to plan the investigation to raise the market sample real estate and carry out the entire valuation process to obtain the market value that allows you to make the corresponding offer.

4. DISCUSSION

There is no doubt about the effectiveness of AHP in decision making. But the valuers have the obligation to consult the original sources of knowledge, never accept a methodological procedure as valid, there is always a need to prove its empirical foundation because that is where the discovery of information enhances the investigation into the science of valuation.

5. CONCLUSION

Based on the ad absurdum argumentative strategy, and with the results of the investigation it was demonstrated that **the alternative hypothesis is false**, therefore, the results of the general weighting vector of the AHP are not linked to the prices of the real estate market. Therefore, the valuation ratio as a mathematical artifice does not guarantee market real estate values.

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